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Dynamic Logics of Networks. Information Flow and the Spread of Opinion

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\abstract

This thesis uses logical tools to investigate a number of basic features of social networks and their evolution over time, including flow of information and spread of opinions.

Part I contains the preliminaries, including an introduction to the basic phenomena in social networks that call for a logical analysis of information and reasoning, a review of background material from logic and social network theory, plus an outline of the thesis.

Part II presents logical models of collective failures, and illuminates how and when sound individual microbehavior can lead to counterproductive collective macrobehavior.
Chapter 3 uses dynamic-epistemic logics of information update to model the phenomenon of informational cascades leading to suboptimal group behavior.
This analysis confirms that perfectly rational agents following the crowd may get stuck in a cascade leading them to make the wrong choice, despite the availability of enough evidence to avoid such a mistake.
We show that this holds under various basic assumptions. Whether agents are full-fledged Bayesian reasoners or use a simpler counting heuristics, and whether they have unbounded higher-order reasoning or not, some misleading informational cascades are simply inescapable by rational means.
Chapter 4 models a second counterproductive social phenomenon, that of pluralistic ignorance.
Using a model based on hybrid logic, we formalize and explain the dynamic properties of this scenario as observed in the social sciences: its stability and its fragility.
As for remedies, we show that, on all but 2-colorable network graphs, changing the behavior of one unique agent is sufficient to reverse the situation entirely.
Together, Chapters 3 and 4 offer a great variety of new update mechanisms for social agents in structured settings.

Part III abstracts from specific case studies to investigate the general logic of diffusion phenomena in social networks, as well as the interaction of information and diffusion dynamics.
Chapter 5 presents a general hybrid dynamic framework to capture the logical laws of the temporal evolution of a wide class of diffusion dynamics, allowing us to plug-in various network update rules.
Using an epistemic extension of this hybrid approach,
Chapter 6 investigates how diffusion dynamics may induce learning by agents who observe how their public behavior evolves in response to social conformity pressure. Finally, Chapter 7 goes one step further, and proposes a minimal framework for modeling the dynamics of threshold models. We show how this setting captures interactions of network properties with diffusion processes, such as the fact that having dense enough clusters in a network prevents full cascades. Adding an epistemic logic-based component, we also show how knowing more about
the network structure and the behavior of agents in the network may accelerate
diffusion in threshold models. Here we study the limit behavior of various diffusion policies: knowledge-independent, first-order knowledge dependent, or higher-order knowledge dependent.

Finally, Part IV presents a summary of our findings, and some ongoing work and perspectives for future research. We discuss modal logics and related formalisms
for studying network behavior under various graph properties and rules of influence. We also discuss the natural transition from network evolution by fixed rules as studied in this thesis to the study of network games where agents have choices and goals.

Overall, this thesis applies tools from current logics of information update and agency to social network analysis and opinion flow over time, offering both tools for detailed modeling of specific scenarios and a better understanding of the general laws of reasoning that underlie information and diffusion dynamics in social settings.